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ANALYSIS OF THE CONSTRUCTIONS AND DRIVES OF THE WORKING ELEMENTS OF THE MECHANISMS FOR THE COMPACTION OF SOLID MUNICIPAL WASTE IN THE DUSTCART

Every year more than 54 mil. m^3 of solid municipal waste is accumulated in Ukraine, 93.8 % of this volume are transported to the landfills and dumps, 2 % are burnt at incineration plants and 4.2 % are directed in the sites of collection of secondary raw materials and waste processing plants. That is why, public utilities of Ukraine must have at their disposal highly productive and multifunctional specialized motor vehicles, in particular, dustcarts, intended for the efficient collection of solid municipal waste (SMW).

The objective of the given research is the analysis of the constructions and drives of the working elements for the mechanisms, intended for the compaction of solid municipal waste in the dustcart for determining the possibilities of their further improvement. The research contains the analysis of the constructions and drives of the working elements of the mechanisms for solid municipal waste compaction in the dustcarts, analyzing the scientific literature sources to identify the possible ways of their efficiency improvement. Hydraulic drive of the working elements of the mechanisms for solid municipal waste compaction in the dustcart is supplied from the pump station of the dustcart. It has been determined that the general problem of this type of machines is the usage of the hydraulic drive on the base of one fixed pump. This creates the situation when for the regulation of the operation speed of the working elements part of the working fluid is directed under high pressure to the hydraulic tank across the relief valve, this results in considerable unproductive power losses.

The study, carried out, confirms that one of the methods for the improvement of the mechanisms of solid municipal waste compaction in the dustcart is the application of the scheme, sensitive to loading. This can minimize power losses of the hydraulic drive in the process of operation, and, in its turn, will improve the efficiency of the hydraulic drive control system of the working elements in different operation modes.

Key words: *construction, hydraulic drive, working element, compaction mechanism, compaction plate, dustcart, solid municipal waste.*

Introduction

Housing and communal services of Ukraine must have at their disposal highly productive and multifunctional specialized motor vehicles, in particular, dustcarts, intended for the efficient collection of solid municipal waste (SMW). Every year more than 54 mil. m^3 of SMW is accumulated in Ukrainian cities, towns and settlement, 93.8 % of this volume are transported to the landfills and dumps, 2 % are burnt at incineration plants and 4.2 % are directed in the sites of collection of secondary raw materials and waste processing plants [1]. Annual increase of SMW volume is 0.5 % [2]. One of the key measures, aimed at ecological safety is timely organization of the collection, transportation, recycling and disposal of solid municipal waste (SMW). Growing requirements, regarding the quality of services, provided to the population, in particular, concerning the sanitation of the territory, determine high standard for the equipment, used for this purpose. Only for the transportation of the waste to the sites of the disposal outside the sanitary zone of 30 km, more than 45 thousand of fuel is consumed every year [3].

Depending on the origin of solid municipal waste, fractional composition, season of the year and weather conditions their density changes within the limits from 100 to 500 kg/m^3. That is why, after unloading of each container of SMW in the hopper of the dustcart the operation of compaction is obligatory performed [4 – 6]. The higher the compaction factor, more efficiently the volume of the hopper and carrying capacity of the dustcart is used [7 – 10]. In the dustcarts of the domestic production the level of compaction is 2.2 times, it is far less than the compaction, performed at the best world items of such equipment. Additional drawback of the insufficient compaction coefficient is incomplete release of the liquid fraction of SMW on the site of the waste collection. As a result, part of this fraction flows on the streets of the settlements, polluting them and decreases the epidemiological stability.

Problem set up

According to the Decree of the Cabinet of Ministers of Ukraine № 265 [11] one of the priority directions of SMW management in Ukraine is the usage of modern highly efficient dustcarts. That is why, the analysis of the constructions and drives of the working elements of the compaction mechanisms of solid municipal waste in the dustcart in order to find ways for their improvement is relevant scientific-engineering task.

Objective and task of the research

Objective of the paper is the analysis of the constructions and drives of the working elements of the mechanisms for the compaction of solid municipal waste in the dustcart in order to find the ways for their improvement.

Methods and materials

Method of the scientific sources analysis is used in the given research.

Main part

Analysis [12] of the trends of improvement of SMW compaction drives in the dustcarts shows that the trend to the efficiency enhancement is traced by means of:

– increase of the compaction coefficient;

– increase of the working pressure in the hydraulic system of the working elements drives, that will decrease the mass of the machine and its production cost.

Fig. 1 shows the scheme of SMW pressing plate drive in the dustcart КО-436 [13, 14].

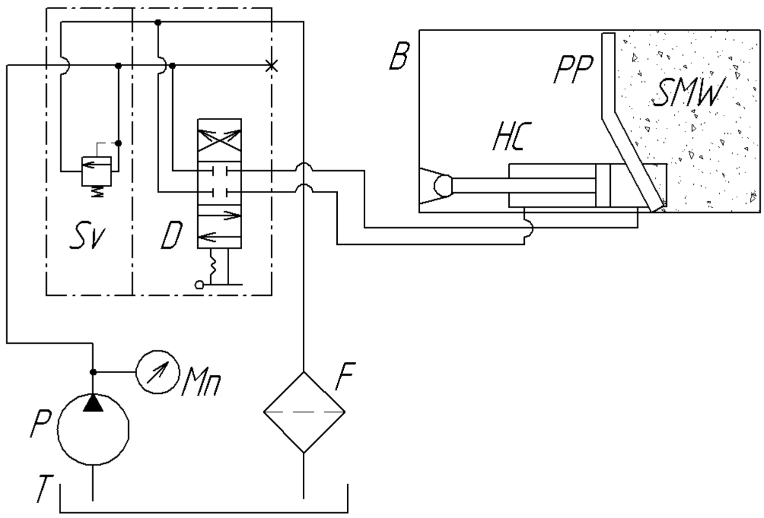

Fig. 1. Scheme of SMW pressing plate drive in the dustcart КО-436: Н (P) – pump НШ50У-2Л of left hand rotation; Б (T) – oil tank; Ф (F) – filter; Р (D) – hydraulic distributor; Кл (Sv) – safety valve; ГЦ (HC) – hydraulic cylinder; К (B) – body of the dustcart, ПП (PP) – pressing plate

Pump is actuated from the power take-off device, installed on the gear box of the motor vehicle. In the process of the power stroke the working fluid (WF) is supplied to the pressure cavity of the hydraulic cylinder via the distributor. At the same time WF via the distributor and filter enters the oil tank. In the process of idle mode of PP WF is supplied to the drain cavity of hydraulic cylinder via the distributor. Simultaneously WF from the pressure cavity of the hydraulic cylinder enters the oil tank via the distributor and filter. Pressure in the hydraulic system is controlled by the manometer (MM) and when the nominal value – 10 MPa is reached safety valve Sv is triggered and excessive pressure is relieved into the oil tank. Such scheme of the hydraulic drive allows to obtain the coefficient of waste compaction of 1.8...2.2, but it is far less than the best world samples.

Fig. 2 shows the scheme of the vibration hydraulic drive of the dustcart compaction plate [15].

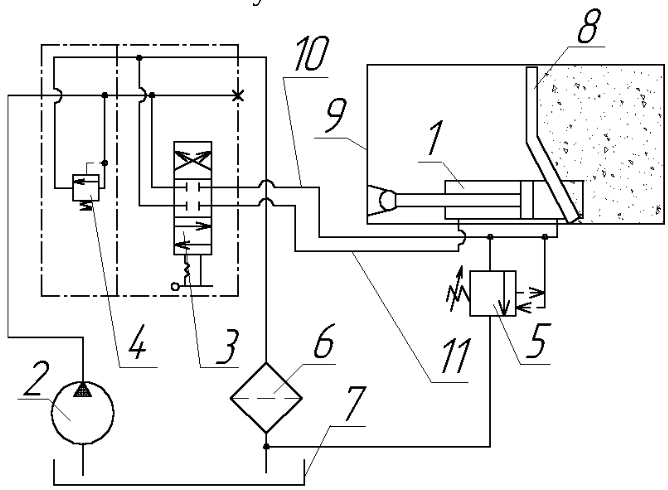

Fig. 2. Scheme of the vibration hydraulic drive of the compaction plate of the dustcart: 1 – hydraulic cylinder; 2 – hydraulic pump; 3 – hydraulic distributor; 4 – safety valve; 5 – pressure pulses generator; 6 – filter; 7 – oil tank; 8 – pressing plate; 9 – body of the dustcart; 10 – pressure mains ; 11 – drain pipe

Vibration hydraulic drive of the compaction plate of the dustcart operates in the following way: after SMW loading in the body 9 of the dustcart, the SMW compaction is carried out by the compaction plate 8. Hydraulic distributor 3 controls the hydraulic cylinder 1. Pressing plate drive 8 provides the motion by means of hydraulic cylinder 1. Hydraulic pump 2 supplies the hydraulic cylinder 1. At the stage of the preliminary pressing the compaction is performed in a stationary mode. After achieving certain value of the pressing effort and corresponding pressure in the pressure mains 10 the generator of pressure pulses (GPP) 5 is triggered. GPP 5 provides the generation of pressure pulses for the vibration compaction of SMW. When the pressure in the hydraulic system is attained as a result of pressing effort excess above the permissible value the safety valve 4 is triggered, which withdraws the working fluid across the drain pipe 11 and filter 6 into the tank 7.

The construction of the dustcart KO-427 is known, the characteristic feature of this dustcart is that SMW is moved by the pressing plate into the body of the dustcart and are additionally compacted by a special (supplying) plate [16]. The scheme of SMW compaction in the dustcart KO-427 is shown in Fig. 3.

After loading of the receiving bucket (Fig. 3, a), the pressing plate goes up, supplying plate 4 lowers down by means of the hydraulic cylinder 11 and covers SMW in the bucket (Fig. 3, b). Further, the prepressing is performed, in the process of prepressing the pressing plate is lowered by means of the hydraulic cylinder 12 and removes SMW from the bucket, pressing it (Fig. 3, c). At final pressing the supplying plate goes up and moves SMW in the body, pressing the waste. Higher compaction coefficient of SMW is obtained (Fig. 3, d).

Authors [17] suggested the construction of the dustcart, where SMW compaction is performed simultaneously in several directions, as a result, the degree of compaction increases in the upper and central part of the body. Diagram of SMW compaction and hydraulic diagram of the dustcart are shown in Fig. 4.

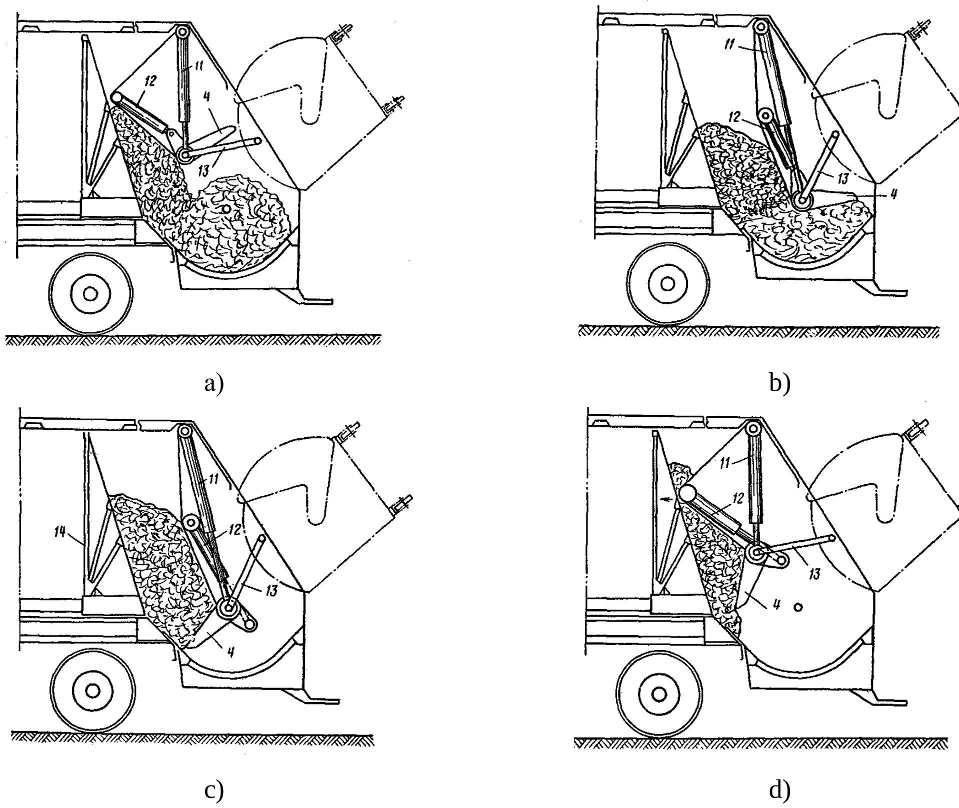

Fig. 3. Diagram of SMW pressing in the dustcart KO-427: a) transfer of SMW from the container into the receiving hopper; b) lowering of the feeding plate; c) prepressing; d) final pressing

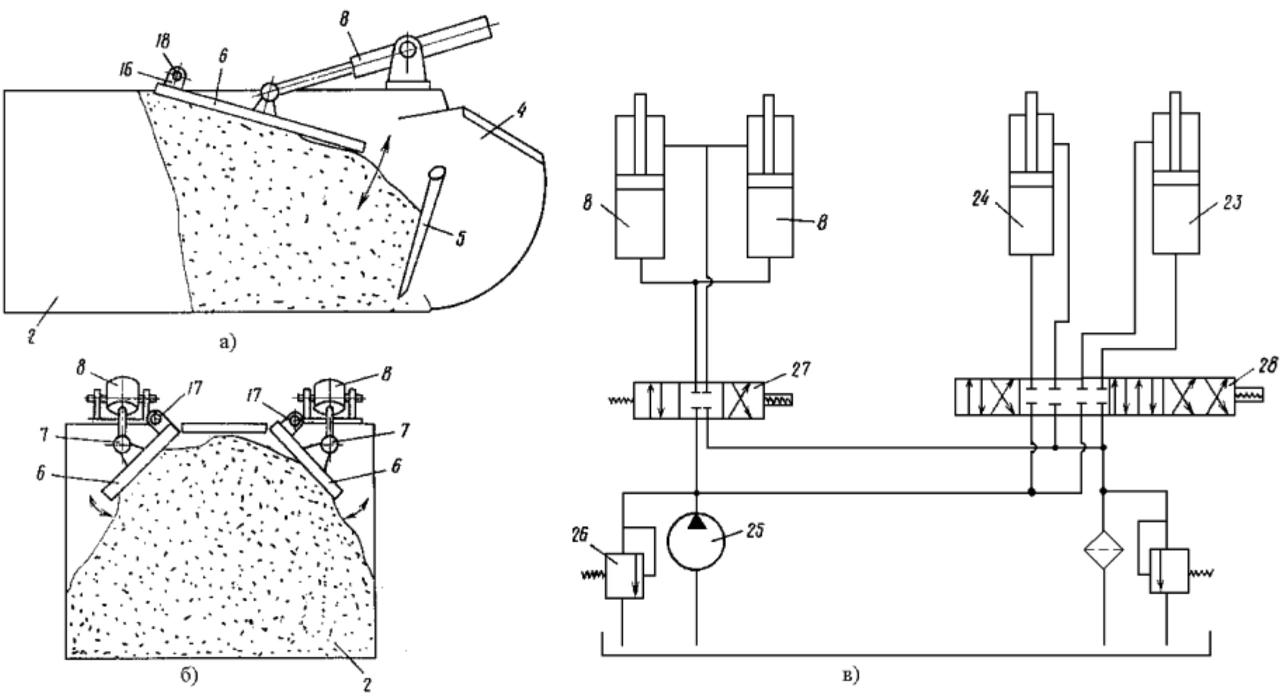

Fig. 4. Flow diagram of SMW compaction and hydraulic circuit of the dustcart: a) in the plane, parallel to the wall of the body; b) in the plane, perpendicular to the wall of the body; c) hydraulic control circuit

Dustcart operates in the following way: SMW is loaded into the hopper 4 and is transferred to the body 2 by the pressing plate 5, filling it to the level of the lid. Then the pressing plate 6 starts operating, the rod of the hydraulic cylinder 23 of the traction drive (not shown in the Fig) and flanges 17 are in elongated position. Fixation of the pressing plate 6 is realized by the flanges 18, which are installed in the lugs 16. While pulling the rods out of the cylinders 8 the first and second parts of the pressing plate 6 rotate around hinges, formed by lugs 16 and flanges 18, compacting SMW in the plane, parallel to the side walls of the body 2 (Fig. 4, a).

After that hydraulic cylinders 8 lift the first and second parts of the pressing plate 6 in the upper position and, switching the hydraulic distributor 28 by means of hydraulic cylinder 23, move forward the tie rod, retracting the flanges 17 into the lugs (not shown in the Fig). In this case, the hydraulic cylinder 24 moves out the tie rod (not shown in the Fig) with the flanges18 from the lugs 16. The next putting forward of the hydraulic cylinders rod 8 provides the rotation of the parts of the pressing plate 6 in the plane, perpendicular to the side walls of the body 2 (Fig. 4, b). As the body is loaded with SMW, by means of the hydraulic distributor 28 the alteration of the pressing plate 6, direction of motion takes place, it is coordinated with the operation of the pressing plate 5. Additional compaction of SMW by the plate 6 can be performed on the route between the sites of waste collection.

Unlike the conventional method of SMW compaction by means of the pressing plate, in the dustcarts ROTOPRESS manufactured by the company FAUN KUKA the waste is pressed by means of the pressing worm in the body, which has the form of the rotating drum [18]. Hydraulic rotating drive of the container consists of the axial-piston regulated pump and axial-piston motor, they are interconnected by the force lock in a closed cycle. Diagram of the hydraulic rotating drive of the dustcurt container ROTOPRESS is shown in Fig. 5.

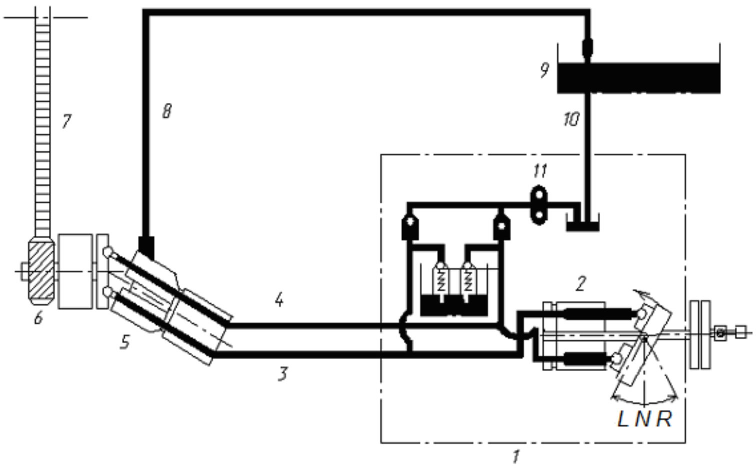

Fig. 5. Diagram of the hydraulic rotating drive of the dustcart container ROTOPRESS: 1 – pumping station; 2 – axial-piston regulated pump (executed in the form of the inclined disk), L – left hand rotation of the container (unloading), N – neutral position, R – right hand rotation of the container (loading); 3 – pipeline of high pressure; 4 – pipeline of low pressure; 5 – axial-piston motor; 6 – drive gear; 7 – gear; 8 – drain pipe; 9 – tank; 10 – suction pipe; 11 – feed pump

Author [19] suggests to increase the degree of SMW compaction at the expense of increasing the motion of the compactor in the vertical direction and SMW spinning at its displacement along the body.

Analysis of the known drives of SMW compaction showed that the waste in the dustcarts are compacted statically, the possibilities of increasing the compaction coefficient, applying this method, are limited. In author`s opinion [15], it is possible to increase the compaction coefficient of SMW, using the vibration pressing technologies, their usage for pressing the powder materials enabled to decrease considerably, as compared with static pressing, the working effort of compaction [20]. But without the preliminary dehydration of SMW usage of the vibrations in the process of waste pressing gives only limited effect. Nowadays, we do not known the constructions of the dustcarts, which use these technologies, this requires the development of new constructions of the dustcarts drives, using the dehydration of SMW and conducting additional studies.

General view of the rotor-inertia device, developed by the authors [21] in the program SolidWorks of the applied package Simulation, is shown in Fig. 6. In the process of the development of the briquetting system construction functional feature of the specialized machines and equipment were taken into consideration. Optimal range of technical characteristics of the device variation are determined by the method of load-carrying calculation, in the process of studying forces and momentum, created by the tensioner, feeding rotor and pressing band.

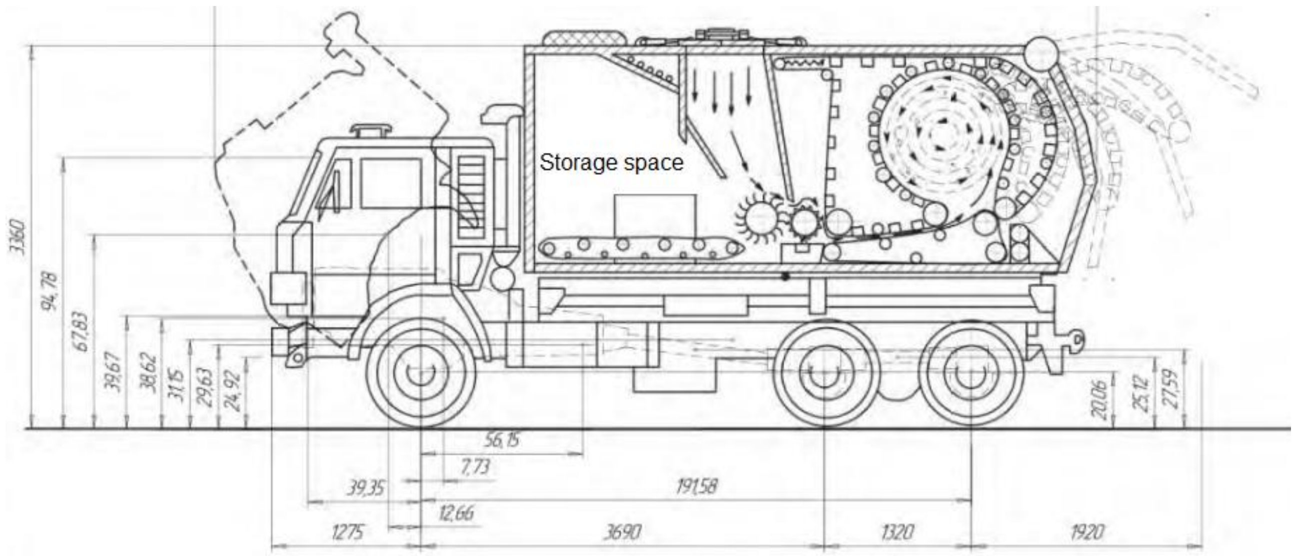

Fig. 6. Scheme of the general view of briquetting rotor-inertia device on the base of KamAZ undercarriage

Fig. 7. shows the mechanical diagram of the briquetting device. Rotor-inertia device consists of the hydraulic motor, triggering the continuous conveyor with the rubberized belts, which rotates and forms the briquetted roll of the stable form. Loading of solid municipal waste in the body is carried out by means of manipulator across the trap door, located in the roof of the body (control console of the operating elements is located on the right side of the motor vehicle), then SMW is supplied by the gripping rotor on the cutting rotor with the knives. While switching on of the hydraulic motor 7 gripping and cutting rotors start rotating, they supply the grinded waste on the lower conveyor 8. At lower conveyor SMW are prepressed by the pressing drum and supplied to the working loop. Working loop is manufactured from the belts, reinforced with the tissue with the transversal bars. This material provides higher density of pressing and carrying capacity. After grinding SMW is supplied to the gap between the pressing drum and lower conveyor. SMW is pressed and transferred to the working loop, where it is rolled up and finally pressed s a result of the twisting effect. When the roll reaches the diameter approximately of 1.4 m and the working loop increases and the idle loop becomes minimal, its sensor triggers binding device. This device binds the roll by means of the selected material (twine, film, net). During transportation of the pressed roll to the landfill the driver by means of control console lifts the body, opens tailgate and the roll will fall on the ground. Then the body should be lowered, close the tail gate, the working loop will return into the initial position, the process of pressing can be repeated.

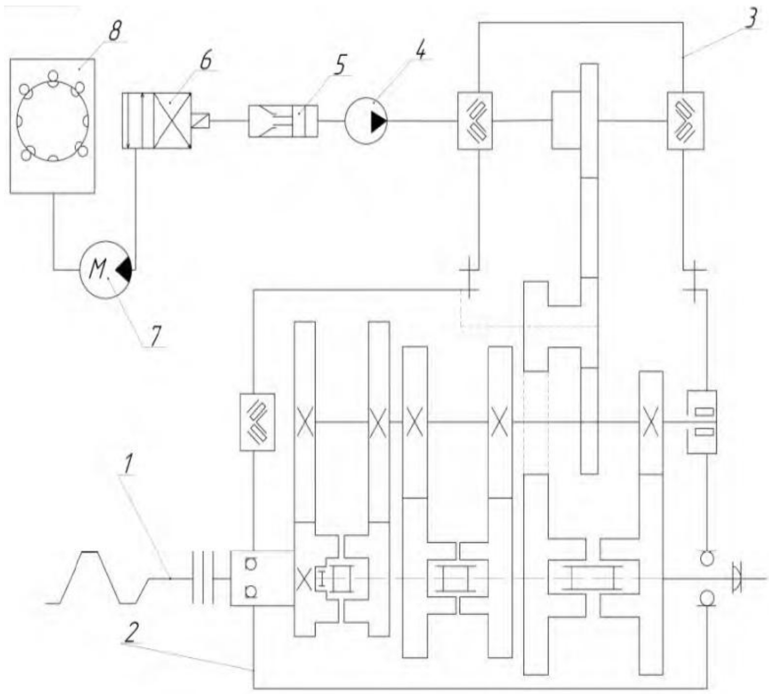

Fig. 7. Mechanical diagram of the briquetting device:
1 – motor, 2 – gear, 3 –power take-off device, 4 – pump 310.256.04У1, 5 – oil filter, 6 – hydraulic distributor, 7 – hydraulic motor, 8 – rotor-inertial device

Materials of the paper [22] contain non-linear mathematical model of the dynamics of SMW pressing plate drive in the dustcart, the model takes into consideration the compressive properties of solid municipal waste and enables to study the dynamics of the given drive and determine the qualitative characteristics of the transient processes during SMW compaction.

Paper [23] investigates the durability of hydraulic drive of SMW pressing, structural and equivalent structural diagrams of the pressing hydraulic drive are constructed, durability area of its transient processes during the startup is determined.

Impact of the materials of the waste pressing plate guides on the dynamics of the hydraulic drive is studied in the paper [24]. Also the impact of the angle of slope of the pressing plate, volume of the container and volume of SMW in the body on the quality of the transient processes in the hydraulic drive is investigated.

Materials of the paper [25] contain the linearized mathematical model of the vibration hydraulic drive for SMW pressing, using the pulse generator of differential action, which enabled to obtain analytical dependences of the frequency and amplitude on the basic parameters of the given drive, these dependences may be used for the execution of the preliminary design calculation of its parameters.

Impact of basic parameters of the vibration hydraulic drive on the vibration indices in the process of SMW compaction is studied in the paper [26]. By means of multifactorial experiment the regression equation for the amplitude, frequency and power of vibration in the process of SMW compaction is obtained.

One of the common drawbacks of this type of motor vehicle is the usage of the hydraulic drive on the base of one fixed pump. Such construction cause the situation when if it is necessary to regulate the speed of the working element, part of the working fluid of the pump, which is under high pressure, is directed across the safety valve to the hydraulic tank, this leads to considerable unproductive power losses. Efficiency of this process can be improved in the hydraulic drives, constructed on the principle of "load sensitive" [27], in this case unproductive losses of power during regulation of the speed modes of the working elements will be reduced.

The research, described in the paper [28], presents the improvement of the hydraulic drive of the support-rotational device with the hydraulic motor of the rotational type. This improvement is based of the scheme, sensitive to loading, that enables to minimize the losses of power in the process of hydraulic drive operation. This approach enhances the efficiency factor of the control system of the hydraulic drive in different operation modes.

In our opinion, one of the methods of improving the mechanisms of solid municipal waste loading in the dustcart is the implementation of the scheme, sensitive to loading. This scheme allows to minimize the power losses during hydraulic drive operation, this will improve the efficiency of the control system of the working elements of the hydraulic drive in various operation modes.

Conclusions

As a result of the analysis, carried out, of the constructions and drives of the working elements of the solid municipal waste compaction mechanisms in the dustcart possible ways of their improvement were revealed. It was determined that the efficient method of the compaction mechanisms improvement is the implementation of the scheme, sensitive to loading. This scheme will allow to minimize losses of power in the process of hydraulic drive operation, it will enhance the indices of efficiency factor of the control system of the working elements hydraulic drive in different operation modes.

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